Economics Bulletin

Volume 30, Issue 4

Pollution Permit Market: Using Incentive Contracts to Reduce Dominant Firm Inefficiencies

Sonia Schwartz
GREQAM, Aix-Marseille University, France

Abstract

Incentive contracts can be proposed to a dominant firm that has been excluded from the pollution permit market. We determine the optimal characteristics of a contract considering the trade-off between market efficiency and the cost of public funds. We show that under incomplete information the firm always buys fewer quotas than under complete information. We conclude this study by giving a concrete rule to implement such a contract.

I would like to thank the anonymous referee for his helpful comments on a previous version of this paper.
Citation: Sonia Schwartz, (2010) "Pollution Permit Market: Using Incentive Contracts to Reduce Dominant Firm Inefficiencies", *Economics Bulletin*, Vol. 30 no.4 pp. 3201-3208.
Submitted: Apr 20 2010. **Published:** December 02, 2010.

1 Introduction

It is widely accepted that pollution permit markets are an efficient mechanism to lead firms to choose the optimal level of pollution reduction (Montgomery 1972). However, if we assume market power (Hahn 1984), pollution permit markets fail to reach this least cost solution[1] and the total conformity cost is not minimized[2]. Moreover, the post-trading equilibrium depends on the initial pollution permit allocation that has been given to the dominant firm. The regulator can theoretically restore efficiency by giving to this potential dominant firm[3] the number of permits that it needs at the competitive equilibrium (Hahn 1984).

In practice however, the regulator only has partial information regarding the emission reduction cost for the firms that are being considered within this market. This asymmetric information between the regulator and the firms prevents the corrective allocation described above from taking place. Hence, in order to deal with market power, the regulator has to exclude the dominant firm from the pollution permit market.

So, a "command and control" regulation can be used for the dominant firm, like a pollution standard. But how to fix this pollution standard? The optimal pollution standard cannot be determined because of asymmetric information[4]. Moreover, reaching in this case the sub-optimal pollution standard can be very costly for the dominant firm. The "command and control" approach cannot solve the trade-off between reducing pollution and buying pollution quotas.

Moreover, we find another limitation to Hahn's proposed approach when we consider the opportunity for governments to raise non-distortionary revenues from permits. In this case, taking into account both objectives - social efficiency and permit revenue - Antelo and Bru (2009) show that the regulator should sell permits to the dominant firm directly, through bilateral negotiation, and auction off the remaining permits to the fringe firms. Under this scenario, the authors find that the dominant firm buys more permits than what is efficient. However, they assume complete information, whereas incomplete information is a crucial issue in environmental regulation.

The purpose of this paper is to suggest an alternative way for dealing with such a dominant firm. Our proposed solution takes into account asymmetric information and the other assumptions discussed above. We determine the incentive contract that can be designed for the dominant firm. We show that the firm always buys fewer pollution quotas than with complete information and that the optimal contract can be implemented by a non-linear pricing scheme. To characterize this optimal mechanism, we restrict our attention to the

[1] This question is crucial, because pollution permit markets are the tool most used today to reduce pollution. We can give, as an example, the European Union Emission Trading Scheme. Moreover, some market power may emerge on this market since only ten firms receive more than the third of the pollution cap (Convery *et al.* 2010).

[2] The total conformity cost is the sum of emission reduction costs for all regulated firms.

[3] We call a "dominant firm", a firm which has the capacity to "set" the permit price because it is able to buy or sell a high quantity of pollution permits relatively to the other firms. This dominant position can be due to technology or/and initial allocations.

[4] Under complete information, the "command and control" regulation is efficient. This is challenged under incomplete information: the regulator sets a pollution standard to the firm but this pollution standard may not correspond to the efficient level.

regular case which assumes the hazard rate is monotonic. This condition is verified by most usual cumulative distribution functions. It excludes bunching contracts where several firms-types receive the same price-quantity pair because, in this case, the contract is not revealing (Laffont 1987).

Different mechanisms have been designed in an environmental regulation context for inducing firms to reveal their private information and a literature review is offered by Montero (2008). In the best of our knowledge, none of the papers reviewed by Montero considers the problem we underlined previously. The framework we use is however close to Spulber (1988) and Mougeot and Schwartz (2008).

This paper is organized as follows. The model and the first-best allocation are presented in Section 2. The second-best policy is analyzed in Section 3. In Section 4 we exhibit a concrete rule to implement the incentive contract and we draw some concluding remarks.

2 Assumptions and the first-best allocation

We assume that one dominant polluting firm is excluded from a pollution permit market. The regulator sells non tradeable pollution quotas to this firm so that it reduces its pollution level, denoted by q. The emission reduction cost is $C(q)$, with $C_q < 0$ and $C_{qq} > 0$. The firm's benefit from polluting is given by $B(q,a) = ab(q)$, where $b(q) = C(\bar{e}) - C(\bar{e} - q)$, and $\bar{e}$ is the steady state level of pollution. Parameter a is specific to the firm. A high parameter implies that it is very costly to abate pollution. The marginal benefit is B_q, and, due to the properties of $C(q)$, $B_q > 0$, $B_{qq} < 0$, and $B_{aq} > 0$, which corresponds to the Spence-Mirrlees condition. If the firm buys q quotas in exchange of a payment t, it has the following revenue:

$$\pi(a,q,t) = ab(q) - t \tag{1}$$

The damage from pollution is given by the function $D(\bar{Q} + q)$, where $\bar{Q}$ is the pollution cap set for the pollution permit market, with $D_q > 0$, $D_{qq} > 0$ and $D_{\bar{Q}} > 0$. Thus, D_q is the marginal damage induced by the supplementary sale of one permit.

The regulator weights the damage and the benefit from pollution with α and $(1-\alpha)$ respectively. Additionally, we assume that there are some distortionary taxes in this economy. The regulator has a secondary objective of raising revenue through the allocation of these pollution quotas, as this enables him to reduce the level of distortionary taxes currently in place. So we take into account the shadow cost of public funds[5] (μ).

In order to determine the first-best allocation, we assume complete information between the regulator and the firm. In this partial analysis, the regulator wants to maximize the firm's profit and the revenue obtained from the quotas' sale, and to minimize the environmental damage. Because of the shadow cost of public funds, the monetary transfer between the firm and the regulator has a social value. Considering the expression of t included in (1), we can express the social welfare as:

$$W = (1+\mu)(ab(q) - \pi) + (1-\alpha)\pi - \alpha D(\bar{Q} + q) \tag{2}$$

[5] This assumption implicitly considers that selling quotas is less-distortionary than free distribution. For a discussion of the literature about the double dividend, see Goulder (1995).

Maximizing (2) with respect to q leads us to the following expression:

$$(1+\mu)ab_{q^*} = \alpha D_{q^*} \tag{3}$$

The firm buys a quantity q^* of quotas such that the weighted marginal benefit is equal to the weighted marginal damage. The overall level of pollution is $\bar{Q} + q^*$. Using the implicit function theorem shows that the quantity sold to the firm increases with a and μ and decreases with α and $\bar{Q}$, revealing several trade-offs. The higher the firm's willingness to pay for the quota, the more quotas it finally receives. The presence of α and μ implies a trade-off between both regulator's objectives of clean environment and revenue. If the shadow cost of public funds is high, the government's revenue objective is significant and it sells more quotas to the detriment of environment. This awarding rule also takes into account the pollution cap decided for the pollution permit market *i.e.* the trade-off between marginal benefit and marginal damage.

Because of complete information, from (1) we obtain:

$$t^* = ab(q^*) \tag{4}$$

The regulator extracts the firm's willingness to pay for pollution quotas: $\pi(q^*, t^*) = 0$. Well-informed about the dominant firm's parameter (a), the regulator is able to implement the first-best allocation of emission reduction. However, in practice, asymmetric information prevents the regulator from implementing this first-best solution and this form of regulation cannot be efficient.

3 Incentive contract under asymmetric information

We now assume that the parameter a representing the private willingness to pay for pollution quotas is private information not available to the regulator. If the regulator asks for a parameter report $(\hat{a})$ from the firm, we must anticipate that the firm will misreport its parameter since $\pi = -(\hat{a} - a)b(q(\hat{a}))$, and $\pi > 0$ if $\hat{a} < a$. Thus, the previous mechanism does not hold under incomplete information. We therefore need to characterize the optimal contract for the sale of pollution quotas under this more realistic assumption.

Assume it is common knowledge that a is the realization of a random variable A, with probability density function $f(\cdot) > 0$ over $\Theta = [a_-, a_+]$, and cumulative distribution function $F(\cdot)$. To avoid bunching, we make the standard monotonic hazard rate assumption, *i.e.* $\frac{1-F(a)}{f(a)}$ not increasing, and we only consider firms for which $a > \frac{(\alpha+\mu)}{(1+\mu)}\frac{(1-F(a))}{f(a)}$ $\forall \alpha, \mu$. These two conditions ensure that the mechanism is incentive compatible.

According to the Revelation Principle (Myerson 1979), we are looking for an incentive compatible mechanism, *i.e.* a direct revealing mechanism that requires the firm to report its parameter a. The optimal mechanism is designed by two functions $\{\bar{q}(a), \bar{t}(a)\}$, which claim that final allocation and payment are derived from the reported parameter $(\hat{a})$. The regulator offers the firm a quantity of quotas $\bar{q}(a)$ in exchange of a payment $\bar{t}(a)$. The firm chooses the quantity and the payment by announcing $\hat{a}$. As the mechanism is incentive compatible, $\hat{a} = a$: the firm chooses to buy the optimal quantity of pollution quotas.

We note that $\{\bar{q}(a), \bar{t}(a)\}$ are solutions of the welfare maximization program (5) subject to participation (6), incentive compatibility (7) and possibility constraints (8). Formally, the government is faced with the following maximization problem:

$$Max_{t(.),q(.)} EW = E_{\Theta}[(1+\mu)t(a) + (1-\alpha)\pi(t,q,a) - \alpha D(\bar{Q}, q(a))] \quad (5)$$

subject to:

$$\pi(t,q,a) \geqslant 0 \qquad \forall a \quad (6)$$

with

$$\pi(t,q,a) = ab(q(a)) - t(a)$$

$$\pi(t,q,a) \geqslant \pi(t(\hat{a}), q(\hat{a}), a) \qquad \forall a, \forall \hat{a} \quad (7)$$

i.e.:

$$ab(q(a)) - t(a) \geq ab(q(\hat{a}, a)) - t(\hat{a}, a)$$

$$q(a) \geqslant 0 \quad (8)$$

Solving this program, we obtain the following conditions characterizing the optimal contract (see Appendix):

$$b_{\bar{q}(a)}[(1+\mu)a - (\alpha+\mu)\frac{(1-F(a))}{f(a)}] = \alpha D_{\bar{q}(a)} \quad (9)$$

$$\bar{t}(a) = ab(\bar{q}(a)) - \int_{a_-}^{a} b(\bar{q}(s))ds \quad (10)$$

From (9), $\bar{q}(a)$ trades off the weighted marginal damage and the marginal benefit corrected by the "weighted virtual signal" of the firm *i.e.* $[(1+\mu)a - (\alpha+\mu)\frac{(1-F(a))}{f(a)}]$. Using the implicit function theorem, we find that quantity $\bar{q}$ increases with a and[6] μ and decreases with α and $\bar{Q}$. As in complete information, there is a conflict between pollution reduction and raising a revenue, but the solving of this conflict is different because it takes into account incomplete information. Comparing the optimal quantity under complete information (3) with that obtained under incomplete information (9), we find the following proposition:

Proposition 1 *Under asymmetric information, the dominant firm always purchases fewer pollution quotas than under complete information.*

When $a = a_+$, $q^*(a_+) = \bar{q}(a_+)$. Moreover, the quantity increases with a. As the bracketed term in (9) is lower under asymmetric information than under complete information, the firm always buys a lower quantity of pollution quotas than under complete information if $a < a_+$. Thus, the global pollution cap given by $(\bar{Q} + \bar{q})$ is lower under asymmetric information than under complete information.

It is well-known that revealing information is costly. In order to raise a higher revenue, the regulator sells more pollution quotas if the firm's willingness to pay a is high. However

[6] We find $\frac{\partial \bar{q}}{\partial \mu} > 0$ if $a > \frac{(1-F(a))}{f(a)}$, which is true under one of our assumptions making sure that the contract is revealing: $a > \frac{(\alpha+\mu)}{(1+\mu)}\frac{(1-F(a))}{f(a)}$ $\forall \alpha, \mu$. This condition obviously holds if $\alpha = 1$ and $\mu = 0$.

in order to induce the firm to reveal its true parameter, the regulator grants it a rent. The firm with the lowest parameter (a_-) gets no rent because it has no incentive to lie. On the contrary, the rent is the highest for the firm with the highest parameter (a_+). Since granting the firm a rent is costly for the regulator, it reduces it by diminishing the quantity sold.

Proposition 1 says that the regulator offers a fully separating contract. This separating contract holds because the hazard rate is monotonic. This monotonic assumption is usual in the incentives literature and is satisfied by many cumulative distribution functions (Laffont 1987). We also neglect some parameters to obtain this regular solution[7]. Taking into account parameters such that $a < \frac{(\alpha+\mu)}{(1+\mu)}\frac{(1-F(a))}{f(a)}$ would also lead to a bunching or pooling contract. Thus, the firm may choose to buy a non-optimal quantity. In this case, using this kind of contract to regulate the dominant firm seems questionable[8].

4 Implementation of the optimal mechanism and concluding remarks

According to the optimal mechanism, the regulator announces the functions $\{\bar{q}(a), \bar{t}(a)\}$ to the firm. As the mechanism is incentive compatible, the firm reveals its true parameter. As usual in economic theory, we seek a way to implement this mechanism. Since $\bar{q}(a)$ is a monotonic increasing function with respect to a, we can define a global payment, as a function of the quantity (Goldman *et al.* 1984). In this case, the regulator lets the firm choose the quantity to buy. Let us denote $\phi(\bar{q})$, the inverse function of $\bar{q}(a)$. Replacing in (10), $\bar{t}(a)$ becomes $\bar{t}(\bar{q})$:

$$t(\bar{q}) = \phi(\bar{q})b(\bar{q}) - \int_{\bar{q}(a_-)}^{\bar{q}} b(\phi(s))\phi'(s)ds \tag{11}$$

This implementation is an example of a non-linear pricing scheme. In this case, the rent being allocated to the firm can be seen as a quantity discount. However, implementing this solution requires the regulator to make sure that pollution quotas are not transferable.

With the presence of a dominant firm in the pollution permit market, one way to restore efficiency is to give it a number of quotas corresponding to its need at the competitive equilibrium (Hahn 1984). Another solution is to exclude the firm from the permit market. In this case, the regulator can use a "command and control" approach to impose an emission reduction. If raising a revenue is also an objective for the regulator then, according to Antelo and Bru (2009), a bilateral negotiation between the firm and the regulator can be used. However, all these forms of regulation need complete information and are inefficient if we relax that condition and assume incomplete information. An alternative is to implement an incentive contract to reach the second-best allocation.

According to this incentive contract, the regulator can raise a revenue, which can be used to achieve the so-called "double dividend". The dominant firm can reduce its emissions at

[7] According to the cumulative distribution function and the value of α and μ, the condition ($a > \frac{(\alpha+\mu)}{(1+\mu)}\frac{(1-F(a))}{f(a)}$) is not very restrictive because this defined threshold may be inferior to a_-.

[8] In another context, to analyze whether it is optimal to have bunching, see Weymark (1986).

low cost, because the incentive contract leads to a trade-off between buying pollution quotas and reducing emissions. This procedure is not detrimental to environment. The pollution permit market remains competitive and the total conformity cost is minimized.

In this article, we have considered one dominant firm and several competitive firms acting in a pollution permit market. Note that the incentive contract that we have determined also applies if there is only one polluting firm in a given geographic area, by fixing $\bar{Q} = 0$. Conversely, this contract is not valid if there are more than one dominant firm. In this case, there is an interdependence between polluting firms and an auction model has to be used.

Appendix

Using the Envelope Theorem, we get from (6):

$$\frac{d\pi(t,q,a)}{da} = b(q(a)) \tag{A1}$$

Integrating (A1) yields:

$$\pi(t,q,a) = \int_{a_-}^{a} b(q(s))ds + \pi(t, a_{i-})\ \forall a \tag{A2}$$

Therefore, after integrating by parts, EW can be written as follows:

$$EW = \int_{\Theta} \{b(q(a))[(1+\mu)a - (\alpha+\mu)\frac{(1-F(a))}{f(a)}] - \alpha D(\bar{Q}+q(a))\}f(a)da - (\alpha+\mu)\pi(a_-)$$

Since $-(\alpha+\mu)$ is always negative, we have $\pi(a_-) = 0$. Then, (10) is obtained from (A2) and (6). After rearrangement, the pointwise maximization of EW leads to equation (9).

References

Antelo, M. and L. Bru (2009) "Permit markets, market power, and the trade-off between efficiency and revenue raising" *Resource and Energy Economics* **31**, 320-333.

Convery, F., D. Ellerman and C. de Perthuis (2010) *Pricing Carbone, The European Union Emissions Trading Scheme*, Cambridge University Press.

Goldman, M. B., H. E. Leland and D. S. Sibley (1984) "Optimal nonuniform prices" *the Review of Economic Studies* **51 (2)**, 305-319.

Goulder, L. (1995) "Environmental taxation and the double dividend: A reader's guide" *International Tax and Public Finance* **2**, 157-184.

Hahn, R. W. (1984) "Market power and transferable property rights" *the Quarterly Journal of Economics* **99 (4)**, 753-765.

Laffont, J. J. (1987) "Toward a normative theory of incentive contracts between government and private firms" *the Economic Journal* **97**, Supplement 1987, 17-31.

Montero, J. P. (2008) "A simple auction mechanism for the optimal allocation of the commons" *the American Economic Review* **98 (1)**, 496-518.

Montgomery, W. D. (1972) "Market in licences and efficient pollution control programs" *Journal of Economic Theory* **5**, 295-418.

Mougeot, M. and S. Schwartz (2008) "Optimal allocation of pollution quotas under asymmetric information" *Revue Economique* **59 (3)**, 505-515.

Myerson, R. B. (1979) "Incentive compatibility and the bargaining problem" *Econometrica* **47**, 61-74.

Spulber, D. F. (1988) "Optimal environmental regulation under asymmetric information" *Journal of Public Economics* **35 (2)**, 163-181.

Weymark, J. A. (1986) "Bunching properties of optimal nonlinear income taxes" *Social Choice and Welfare* **3 (3)**, 213–232.